Pi recommendations

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Pi recommendations

[http://arxiv.org/abs/arXiv:1802.07237]

In your SMEFT fits, please always provide:

1. **individual (also by process) and global constraint**
2. **information on the energy scales probed by the process**
3. **constraints using i) linear and ii) linear+squared terms**

If possible, please use:

π. the best predictions available for a given observable

What is LO? What is NLO?

LO is an acronym which stand for Leading Order. NLO means Next-to-LO.

LO means the order of a perturbative computation of a given observable which is leading, i.e. the most important term parametrically and/or numerically. NLO means the next one in the perturbative expansion.

LO is, normally but not always, the first non-zero term in a perturbative expansion. It is not when the first term is zero or anomalously small for special reasons. For example, the inclusive Higgs production cross sections from gluons, gg>H starts at one loop in the SM. So it's a LO contribution at one loop. The same for gg>Hg contribution to pp>Hj or gg>HH to inclusive HH production. Another example, is pp>Wj. One can see that qg>qW is subheading with respect to the tree level contributions qg>qgW or qq>qqW in the cross section of Wj at high pT for the jet.

One can use other definitions and come up with all the academic motivated counting he wants, even including Pi's. At the end, the only thing that counts is how accurate/precise is your prediction numerically, compared to data. So it's certainly not useful to call a contribution NLO as an excuse not to consider it, if it is important or even leading in the calculation of your observable.

Backup slides

Squared terms are relevant

At the amplitude level:

$$A = A_{\rm SM} + \sum_i \tilde{c}_i^6 A_i^6 + \sum_k \tilde{c}_k^8 A_k^8 + \ldots \quad \text{(*)}$$

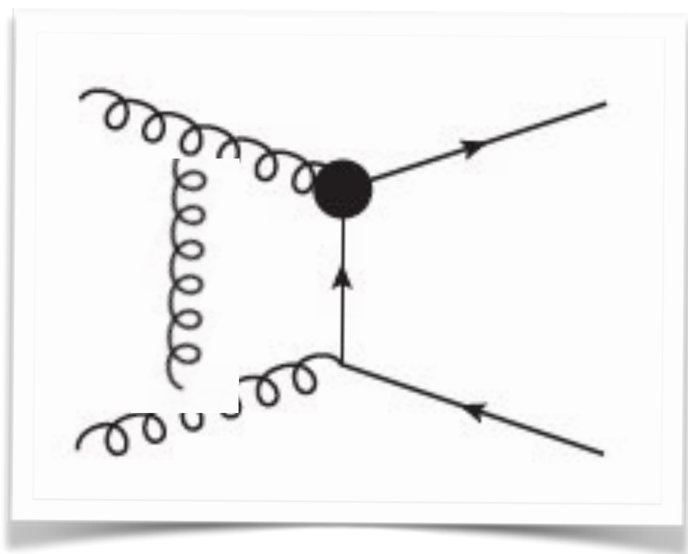
At $1/\Lambda^2$ level, the dim=6 term is uniquely defined. One can change the basis, perform field redifinitions, use the EOM, yet the full blue sum remains the same, generating however, corrections of order $1/\Lambda^4$, feeding into the red term . This means that

$$|A|^2 = |A_{\rm SM} + \sum_i \tilde{c}_i^6 A_i^6|^2$$
$$= |A_{\rm SM}|^2 + 2\sum_i \tilde{c}_i^6 \,{\rm Re}\left[A_{\rm SM}^* A_i^6\right] + \sum_{ij} \tilde{c}_i^6 \tilde{c}_j^{6*} A_i^{6*} A_j^6$$

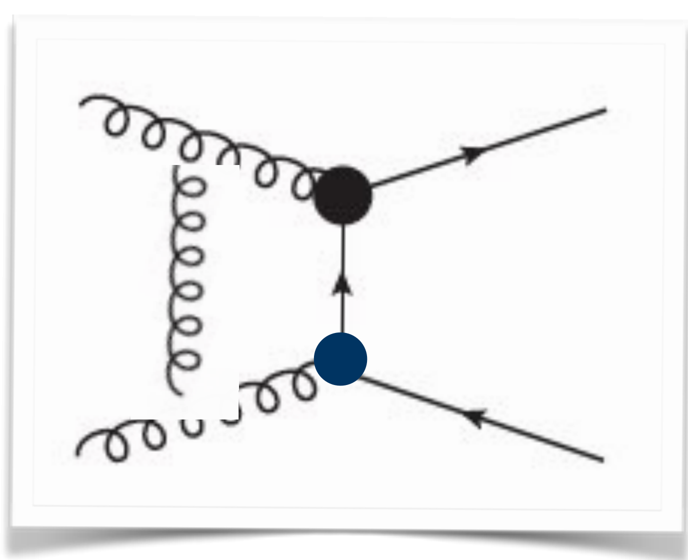
is parametrisation invariant. The last term is order $1/\Lambda^4$, yet uniquely defined.

(*) I am including in the dim=8 term also double insertions of dim=6, see next slide.

Squared terms are relevant



This amplitude will need max dim=6 operators for renormalisation



This amplitude will generically need dim=8 operators for renormalisation (= double insertions are like dim=8)

Squared terms are relevant

In many cases the squared term should be included and in any case can be included:

1) If the interference term is highly suppressed because of symmetries (such as absence of FCNC at the tree-level in the SM) or selection rules (helicity selection for VV productions, i.e. the GGG operator in gg→gg), the squared term is always the dominant contribution.

2) There are UV models, for which the squared terms are foreseen to be the dominant $1/\Lambda^4$ contributions:

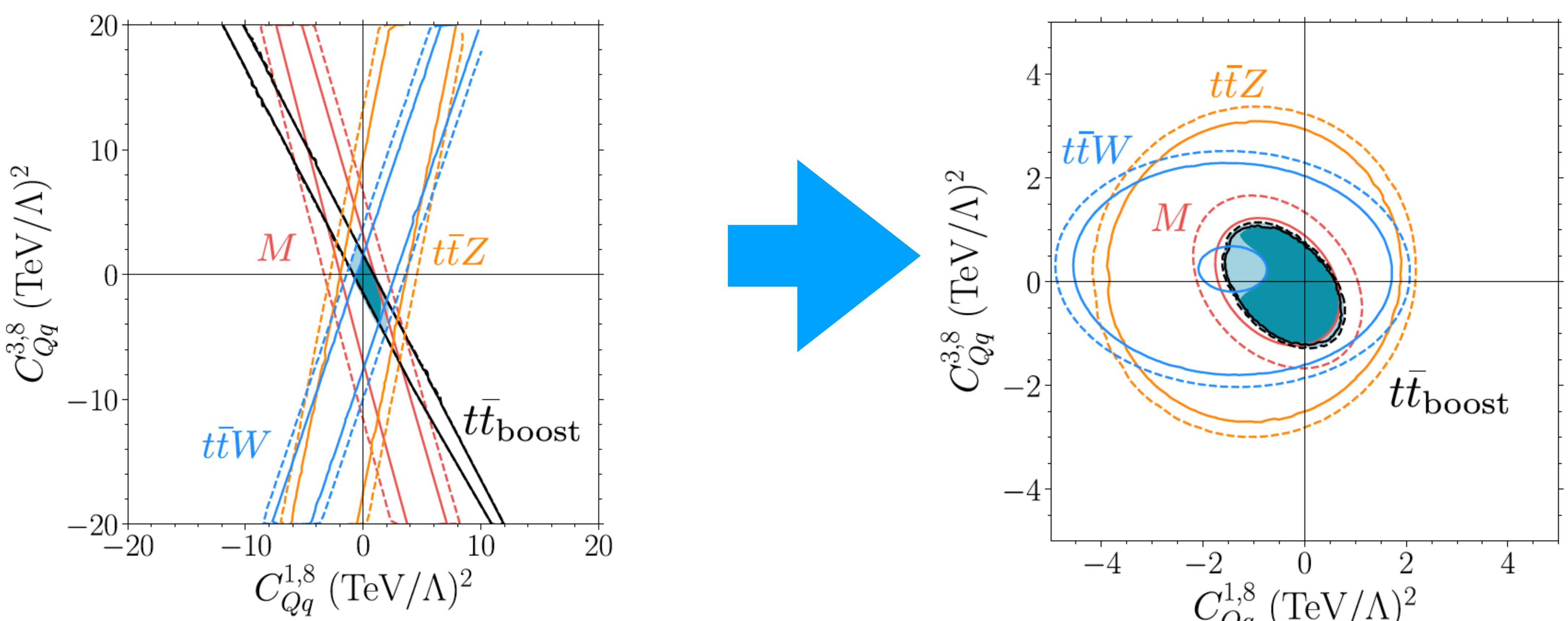
$$\left(c_6 \frac{E^2}{\Lambda^2}\right)^2_{\mathrm{sq}} > c_6 \frac{E^2}{\Lambda^2} > c_8 \frac{E^4}{\Lambda^4} > 1 > \frac{E^2}{\Lambda^2}$$

EFT condition satisfied but $O(1/\Lambda^4)$ large for large operator coefficients

Squared terms are relevant

At the fitting level the squared can have an important effect, as there are no flat directions in the fit with the squares:

[Brivio et al. , 1910.03606]



In general without knowing the effect of the squares one is left in the dark about the meaning/reliabilty of the fit.

Provide constraints using i) linear and ii) linear+squared terms

Fits of single parameters

It is true that the SMEFT approach is global in nature. This is due to RGE, reparametrisation invariance, and so on. However, individual constraints and constraints on subsets are extremely useful. For example:

1. To understand which process is the most constraining one (comparing the impact of an operator on different processes is normalisation independent) SENSITIVITY.

2. Using pairs or triplets to understand the correlations and the flat directions and how to break them.

3. Technically, it might be complicated to include all operators in an analysis. However, having previous knowledge about where the sensitivity of an operator comes from, bounds from other processes/experiments, RGE information and, if desired, also UV model dependent information, one can establish a hierarchy and make maximal use of experimental information.

*** Provide individual (also by process) and global constraints ***

Validity/perturbativity of an EFT

A necessary condition for the EFT to be consistent is the E<Λ. However, predictions depend on c_i/Λ^2

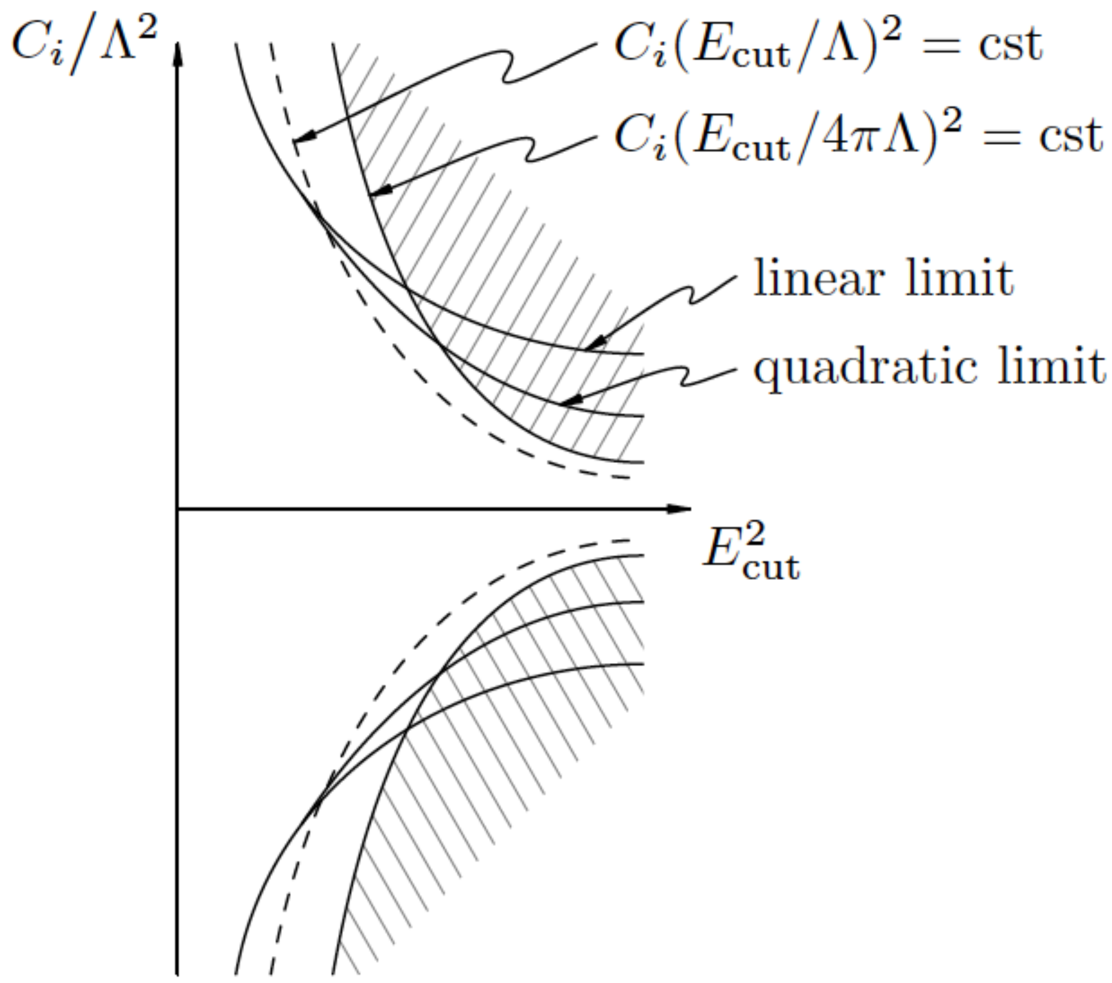


Figure 1: Illustration of the limit set on an EFT parameter as function of a cut on the characteristic energy scale of the process considered (see item 6). Qualitatively, one expects the limits to be progressively degraded as $E_{\rm cut}$ is pushed towards lower and lower values. At high cut values, beyond the energy directly accessible in the process considered, a plateau should be reached. The regions excluded when the dimension-six EFT is truncated to linear and quadratic orders are delimited by solid lines (see item 5c). The hatched regions indicate where the dimension-six EFT loses perturbativity (see item 7). In practice, curves will not be symmetric with respect to $C_i/\Lambda^2 = 0$.

*** Provide information on the energy scales probed by the process ***

NLO EFT will be a useful step

Understanding and quantifying the higher order effects in the SMEFT is needed because of many reasons:

1. The structure of the theory manifests itself when quantum corrections are known, such as for example mixing/running and relations between operators at different scales.

2. NLO brings more accurate central values (k-factors) and reduction of the uncertainties (which can be gauged with the scale dependence, including EFT.

3. NLO QCD effects are important at the LHC, due to the nature of the collision. Not only rates can be greatly affected but also distributions.

4. At NLO genuine new effects can come in, such as the appearance of other operators due to loops or real radiation.

5. NLO can reduce the impact of flat directions.